DESALINATION

New numbers reopen desal technology war

A comprehensive new analysis of primary energy consumption shows that reverse osmosis is undisputedly the most efficient desalination technology, but low cost heat from the sun could revitalise thermal desalination in the longer term.

Low cost concentrated solar power could turn the economics of desalination on their head. That is one of the messages from a new study of energy consumption in desalination which compare technologies on a level playing field for the first time. It confirms that reverse osmosis is ultimately the most efficient technology whatever the energy source in terms of energy consumption, but in terms of the overall cost of water, other technologies may prevail in the longer term as solar thermal technology evolves.

The research was undertaken by one of the industries most successful power and water developers, ACWA Power VP for Technology Thomas Altmann and one of the most respected academics in the field, Professor John Lienhard of the Massachusetts Institute of Technology. The results have been published in Elsevier's *Applied Energy* journal.

Previous comparisons of energy consumption in desalination have been based on converting the energy in steam from British thermal units into kilowatt hours to get a direct comparison between thermal energy and electrical energy. The problem with this approach is that proponents of thermal desalination technologies typically argue that they use "waste" heat and that its value should be discounted. The approach advocated by Altmann and Lienhard settles the disputed value of "waste heat" once and for all by calculating the additional primary energy consumed by the desalination process to supply the "waste heat".

The study compares the specific primary energy consumption in kWh/m^3 for the five most established desal technologies (reverse osmosis, stand-alone, multi-effect distillation, MED with thermal vapour compression, and multiple stage flash) as well as two emerging technologies: forward osmosis (from Trevi System) and membrane distillation (from Memsys). It is based on actual commercial energy consumption values obtained by ACWA Power, although assumptions have been made about the scalability of the two emerging technologies. It brings to an end the on-going debate about the relative energy efficiency of currently commercial desalination technologies, and creates the benchmark against which all future desalination technologies will be judged. It potentially has much broader implications for desalination technology as well.

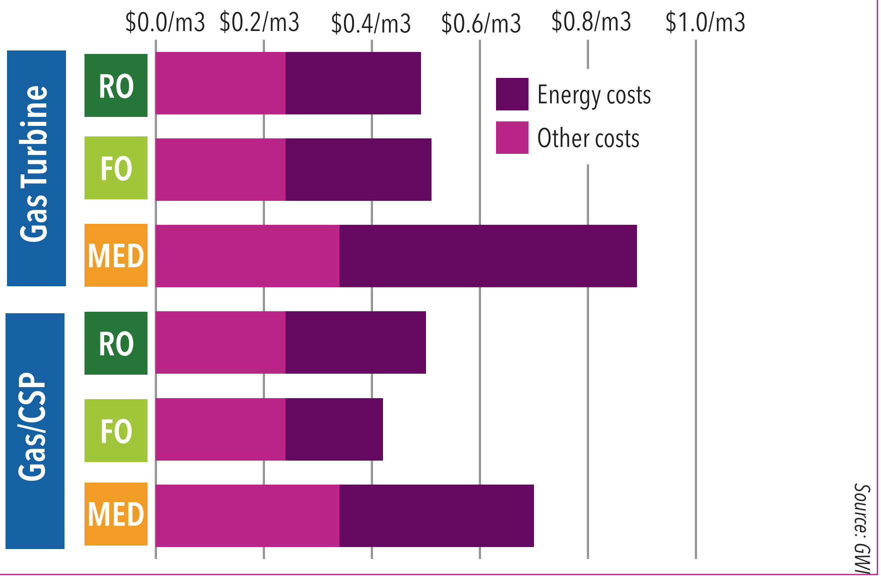
Although study does not address the issue of cost, by implication it sets the target for the how much a kWh of thermal energy has to be priced at before alternative technologies become viable. On the assumption that heat energy from a concentrated solar power tower costs around $0.079/kWh, it would only take a 13% reduction in the cost of heat energy to make forward osmosis with thermal separation competitive with RO (assuming FO technology can be viably scaled up). It is also not impossible that MED could come back into contention if solar thermal energy can be made more economic. Using steam from conventional power plants is not and is never likely to be energy efficient because these plants have been so well optimised that the opportunity cost of steam is high.

Other findings of the study include:

- Of the two novel desalination methods studies forward osmosis performs very much better than membrane distillation. This does not necessarily mean that MD is a non-viable desalination technology. The fact that it is largely based on injection moulded plastic means that it has a low capex cost. Furthermore the study was based on older Memsys units rather than the more efficient Evcon units which now represent the state of the art.
- Hybrid systems RO-thermal systems can be more efficient than the average efficiency RO and MED or MSF separately. This does not necessarily mean hybrids are cost effective: additional processes add to the capital costs of projects.

DOES SOLAR OPEN THE WAY TO $0.40 DESAL?

The Altmann/Leinhard study kills the myth of waste heat in desalination, but it doesn't remove all hope for alternative desalination technologies. Instead proponents of "waste heat" desal can use the data as a starting point for exploring ways of lowering the cost of heat for desalination. For example what if CSP towers were designed to heat water for desalination instead of generating electricity? The expensive bits of a CSP plant are the power block and the moulten salt system. Cut them out and you could produce hot water for thermal desalination or the second stage separation process in forward osmosis for half the price that heat from a CSP tower currently costs. The chart below shows what the cost of desal would look like from RO, MED and FO taking electricity from a gas turbine at $0.078/kWh and heat from a heat-only CSP tower at $0.039/kWh. The other costings are estimated based on ACWA Power's $0.49/m3 Taweelah project with the assumption that the non-energy costs of FO are the same as RO and the non-energy costs of MED are 40% more than RO. It takes the price of water down to $0.42/m^3, but it depends on FO being scalable (and potable) as well as coastal CSP using seawater as a heat sink being financial and environmentally viable.

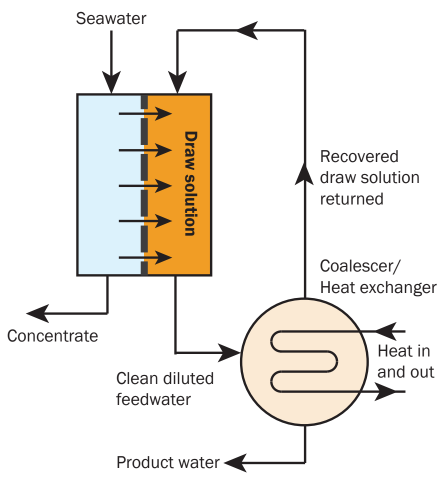


- Nanofiltration pretreatment for thermal desalination is shown to be energy efficient, but again this does not take into account the capital cost implications.
- Thermal Vapour Compression does not pay its way in energy terms when added to MED because it requires high pressure steam which draws more heavily on primary energy. MED-TVC can still an economic proposition however because low pressure steam requires much larger pipes making it expensive and impractical to move around a large plant.

All of the values used in the study are currently commercial, but competitors should be warned that ACWA Power is not sharing the performance data on which its recent run of successful desal project bids have been based.

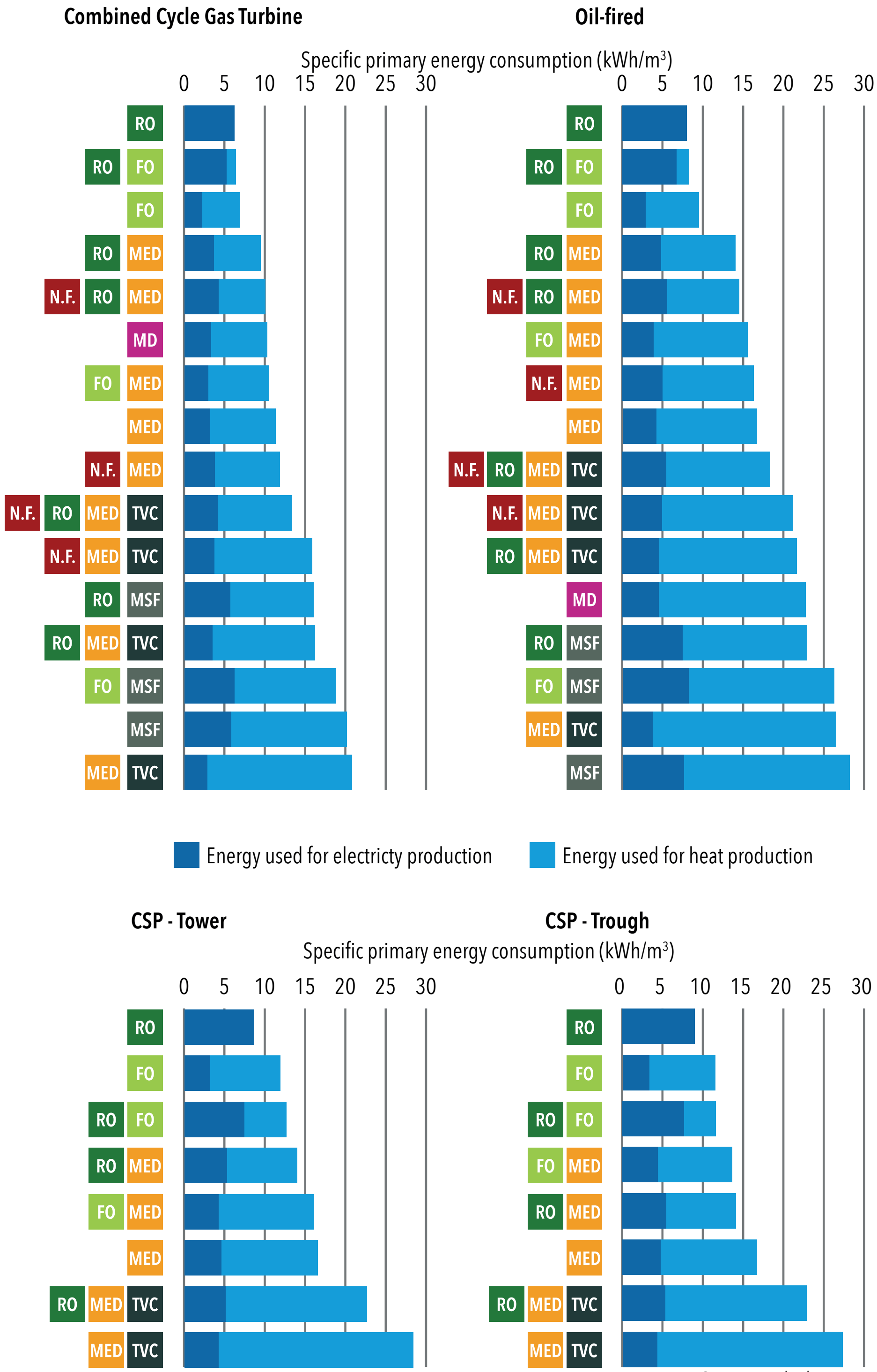
CAN FO BE SCALED UP?

The surprise result of the study is that forward osmosis is so competitive in energy terms. If solar power can reduce the cost of the heat the technology requires, then the technology could see strong growth in the future. The research used data related to Trevi Systems technology to calculate the energy consumption of forward osmosis. Thiers is a two stage process which relies first on water molecules from seawater passing through a membrane to dilute a much more concentrated polymeric draw solution, and then separating out freshwater from the draw solution by heating it up. Although the technology has been used for small pilot projects around the world, it has not yet been tried at large scale. Besides its reliance on low cost heat energy to separate out the draw solution, the other drawback of the technology is the draw solution itself. It is an ethylene oxide-propylene oxide copolymer which might not impress drinkingwater regulators. On the positive side FO systems, unlike RO systems do not operate at high pressure so the equipment should be cheaper.



HOW MUCH ENERGY DOES DESAL REALLY NEED?

The chart below shows how much primary energy is consumed by various permutations and combinations of desalination technology to create a cubic metre of water. Casual readers should be reminded that by primary energy we mean the energy - either fossil fuel or solar - going into the generating process that makes heat or electricity rather than the actual energy consumed by the desalination process (hence the reason why RO driven by a gas turbine uses 6kWh of primary energy rather than 3.5kWh of actual electricity). It shows that while RO is always the most efficient, the order of efficiency of other technologies which rely on heat energy depends a lot on how the heat is generated. It comes from a paper entitled *Primary energy and exergy of desalination technologies in a power-water cogeneration scheme* by Thomas Altmanna, Justin Roberta, Andrew Boumab, Jaichander Swaminathanc,and John Lienhard published in Applied Energy journal.



Source: Applied Energy